Received: 14 September 2021 | Revised: 3 January 2022 | Accepted: 10 January 2022

DOI: 10.1111/faf.12644

ORIGINAL ARTICLE

FISH and FISHERIES WILEY

Mapping small-scale fisheries through a coordinated participatory strategy

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Abstract

The knowledge of small-scale fisheries (SSFs) is important to develop management policies and mitigate the competition for marine resources. However, spatially explicit information is often unavailable at the regional and subregional scale. We designed and tested a novel participatory approach to map the SSF fishing effort using the Mediterranean sea as a case study. We applied the approach in eight countries (Albania, Croatia, Italy, Libya, Malta, Montenegro, Slovenia and Tunisia) characterized by different cultural, social, political and ecological features. The results provided quantitative and spatially explicit information on fishing operations on a fine-scale resolution, contributing to overcome the pragmatic and budgetary constraints that to date have prevented an accurate assessment of SSFs worldwide. This novel participatory approach is inspired by the principles of governance, adaptive management, cross-national cooperation and spatial planning, thus supporting the ecosystem approach to fisheries and has the potential to provide a useful complement to traditional assessments.

KEYWORDS
data-poor fisheries, fishing effort, geographical information systems, local ecological knowledge, marine spatial planning, participatory mapping

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Small-scale fisheries (SSFs) are a substantial segment of global fisheries, accounting for about half of the world's catches in absolute terms and for two thirds of the fish destined for direct human consumption (FAO, 2015). It is difficult to agree upon a clear definition of SSFs worldwide and, at present, the terms "artisanal fisheries" and "small-scale fisheries" are often used interchangeably. The FAO Fisheries Glossary (Garcia, 2009) defines these fisheries as "traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for local consumption". However, the definition of SSFs varies between countries, for example in Europe the European Maritime and Fisheries Funds defines SSF as "fishing carried out by fishing vessels of an overall length of less than 12 m and not using towed fishing gear". According to recent estimates, SSFs involve over 90% of the 4.36 million fishing vessels in the world and up to 35 million fishers (FAO, 2021d), supporting crucial economic, social and cultural human activities worldwide (Stewart et al., 2010). Despite their importance, and unlike large-scale demersal and pelagic fisheries, SSFs are historically under-reported, under-monitored, and under-managed (Mills et al., 2011); as a consequence even basic knowledge of this sector is still limited (FAO, 2015b; Jacquet & Pauly, 2008). Moreover, whereas large-scale fisheries rely on electronic logbook-ID-type tracking systems such as Vessel Monitoring System and Automatic Identification System (AIS) (Johnson et al., 2017), SSF vessels are often not subject to electronic monitoring, which results in a total lack of spatial information (Behivoke et al., 2021; James et al., 2018; Tassetti et al., 2019; Thiault et al., 2017). The problem is compounded by the intricacies of SSF social-ecological systems, which are hard to monitor and to manage appropriately (Allison & Ellis, 2001; Cardiec et al., 2020; Kavadas et al., 2016). Additional challenges are related to the sheer magnitude of SSF spatial distribution in the world's coastal environments, which makes SSF assessments extremely difficult when moving beyond the local scale. Yet, the growing interaction with other economic sectors (Adger, 2006; Finkbeiner et al., 2018) and the need to understand the impacts of large-scale drivers (e.g. climate change, overfishing and invasive species; (Berkes et al., 2006; Macusi et al., 2020)) require increasingly shared policy strategies for SSF management and adaptation (Berkes et al., 2006; FAO, 2018). Therefore, there is a pressing need for an exhaustive assessment of SFF at the regional scale to balance short-term needs with long-term sustainability (FAO, 2018), which is considered as a key objective for common governance (Andrew et al., 2007).

One key area where information is critically needed is fishing effort spatial representation (Behivoke et al., 2021; Johnson et al., 2017). Indeed, SSFs mostly operate in coastal areas, where they may have to compete for space and resources with multiple users such as aquaculture, offshore energy production, maritime transport and recreational fisheries (Douvere, 2008; Jentoft, 2017), a situation that may lead to 'ocean grabbing', where small-scale fishers risk losing their rights to access or use ocean space or resources (Bennett et al., 2015). Marine Spatial Planning (MSP), a coordinated, integrated and transboundary approach for the sustainable coexistence of multiple uses in the maritime space (Directive 2014/89/EU (European Union, 2014)), is a process through which such conflicts could be minimized or avoided.

Several national and international governmental bodies are actively promoting regional monitoring strategies to support the sustainable use of marine resources and the adoption of the

Ecosystem Approach to Fisheries (EAF) (Garcia et al., 2003). In this regard, the Regional Plan of Action for Small-Scale Fisheries in the Mediterranean and the Black sea (RPOA-SSF) of the General Fisheries Commission for the Mediterranean (GFCM) commits Mediterranean countries to undertake concrete actions until 2028 to strengthen and support sustainable SSFs in the region (FAO-GFCM, 2018). The RPOA-SSF was signed by 19 countries with the aim of establishing goals, principles and concrete actions ensuring the long-term environmental, economic and social sustainability of the sector; one of its specific aims is to improve the collection of relevant data on SSFs.

Achieving the latter objective requires novel cost-effective observation strategies, especially considering the current scarcity of economic resources. In this context, the expert knowledge of local fishers can be harnessed to gather spatially explicit information on a wide range of social, ecological and data availability contexts (Selgrath et al., 2018; Thiault et al., 2017). The results, especially cartographic outputs (e.g. (Dunn, 2007)), can effectively inform policy and management bodies on a variety of environmental and socio-economic issues (e.g. (Azzurro & Cerri, 2021; Gill et al., 2019)). Participatory approaches—which promote public involvement, stimulate new partnerships and facilitate co-management processes—have an intrinsic and widely recognized value (Kindon et al., 2007; Reid et al., 2020). These considerations explain why participatory mapping is increasingly recommended to meet the aims and requirements of fisheries policies (Gray & Hatchard, 2003; Symes, 2007), particularly the EAF (Long et al., 2017).

Some notable initiatives, such as the Public Participation Geographical Information Systems (Brown & Fagerholm, 2015), support the collection of local spatial knowledge for the sustainable use of natural resources (Brown et al., 2012; Dunn, 2007; Levine & Feinholz, 2015; Loc et al., 2021), also by SSFs (Gill et al., 2017; Lèopold et al., 2014). Indeed, several experiences demonstrate that involving fishers in data collection and management decisions may be the most effective way to improve data quality and accessibility (FAO, 2009; Leite & Pita, 2016; McCluskey & Lewison, 2008), especially in data-poor contexts (Berkström et al., 2019; Lopes et al., 2019). Despite their increasing use in fishery resource monitoring, participatory approaches have seldom been used over large geographical scales such as regional monitoring programmes (Dalsgaard, 2012). Yet, recent experience indicates that this can be achieved through appropriate macroregional coordination and harmonized and cost-effective procedures (Azzurro et al., 2019), thus overcoming the common difficulties—primarily funding, survey design, coverage and implementation—hampering this type of actions.

Based on these considerations, we designed a novel participatory approach to estimate and map the SSF effort over a broad spatial scale. The method was conceived and implemented through a coordinated strategy and applied in the Mediterranean region, which was considered as an ideal testing field due to its varied cultures, strong seasonality and the diverse fishing gear configurations, fishery resources and habitats exploited by SSFs (Coll et al., 2013; Grati et al., 2018).

This paper describes the method, its application and the results achieved in the Mediterranean region.

2 | METHODS

2.1 | Coordination strategy

The study was performed in eight Mediterranean countries through a coordinated effort supported by the FAO Regional Projects AdriaMed (FAO-AdriaMed Project, 2021) and MedSudMed (FAO-MedSudMed Project, 2021). An international team of 18 scientists with strong connections with local fishery communities were trained to interview SSF actors in Albania, Croatia, Italy, Libya, Malta, Montenegro, Slovenia and Tunisia (Figure 1). The tuning and dissemination of the approach was carried out from 2017 to 2019 through four training sessions and seven meetings organized by AdriaMed and MedSudMed in Italy and Tunisia. Training included both theoretical sessions and joint field surveys with local fishers. Scientists were guided in performing standardized interviews and advised on how to select the respondents, conduct the interviews, collect the data and reduce potential biases.

2.2 | The participatory mapping process

The process of participatory mapping was guided by a 7-member coordination team of fishery scientists, who conceived a set of actions according to three different operational levels.

1. *Coordination level*: this involved developing key methods and monitoring strategies, designing training modules, identifying data validation criteria and implementing a common Geographical Information System (GIS) database.
2. *International workshops*: four workshops were held in three Mediterranean countries. Initially, during the meetings, preliminary methodological proposals were discussed to achieve a common and harmonized strategy. Subsequent meetings were opportunities to train local experts on data collection, digitization and GIS mapping (Figure 1). The workshops also allowed to check and validate the data collected in the different countries and to enter them in the common GIS database.
3. *Country level*: the 18 trained scientists applied the common methodology at the local level. Their work resulted in 497 fisher interviews in eight countries. Data were stored in eight national interoperable databases and allowed mapping the SSF fishing effort for each Country - Geographical subarea (GSA) - Gear - Target taxa combination.

2.3 | Interviews

Data were collected in individual face-to-face interviews from January to December 2019. Respondents were selected by local

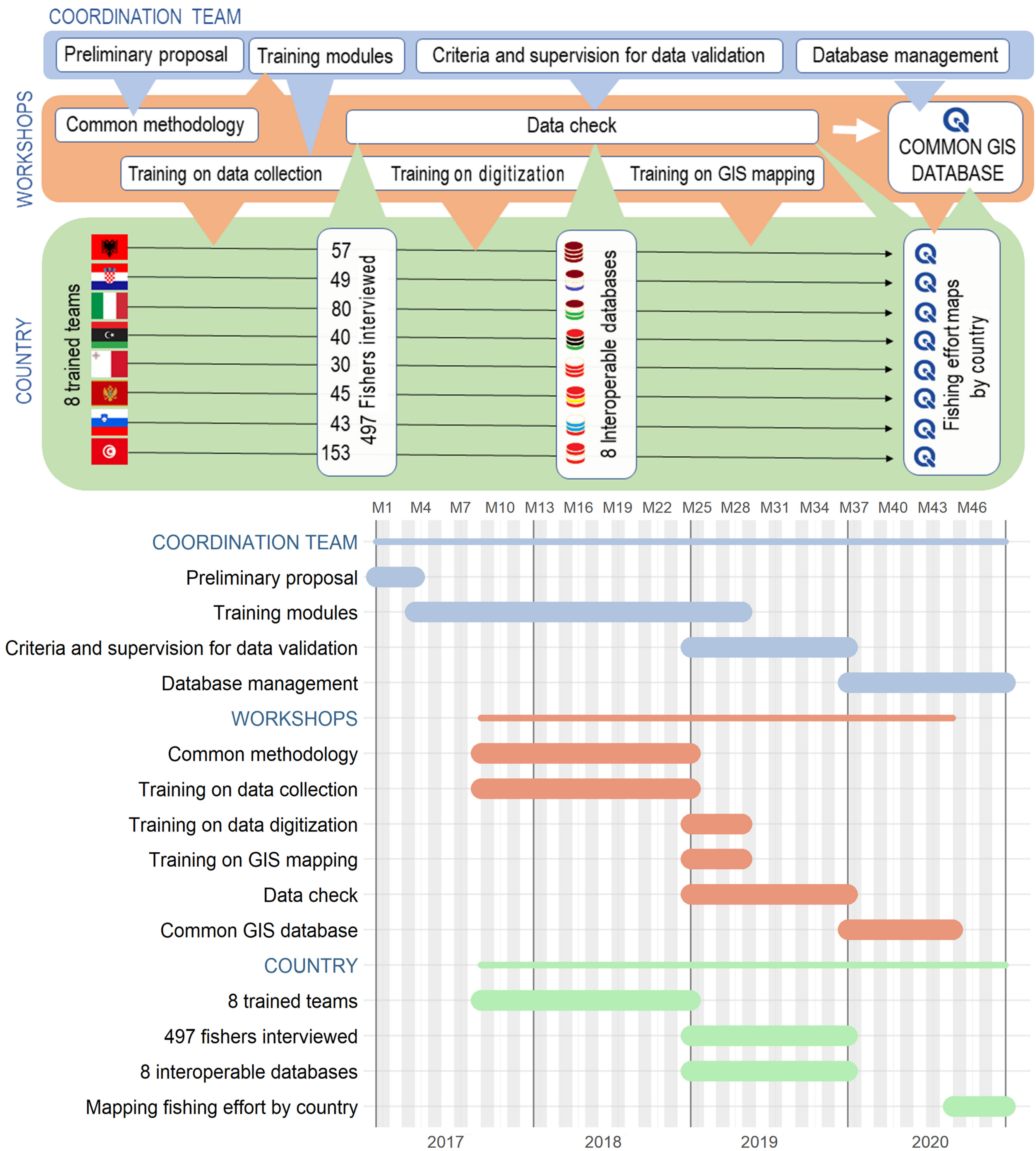

FIGURE 1 Schematic representation of the coordinated participatory mapping process adopted to characterize the SSF fishing effort in the Mediterranean sea

research teams among the most reliable and knowledgeable active small-scale fishers. The study area consisted of about 12,000 km of coastline, corresponding to 25% of the Mediterranean coast, and included GSAs 12, 13, 14, 15, 16, 17, 18 and 21 (Figure 2).

Spatially explicit information was collected on the basis of printed gridded maps of the coastal areas surrounding each location. After explaining the aims of the interview, the local maps were shown to each fisher to verify their map reading ability. Afterwards, fishers were asked to identify their own fishing grounds according to the scale mapping methodology (Corbett, 2009). Local knowledge was gathered in conversation around the map; the fishing grounds were drawn on it directly by the respondents. Fishers were also asked to

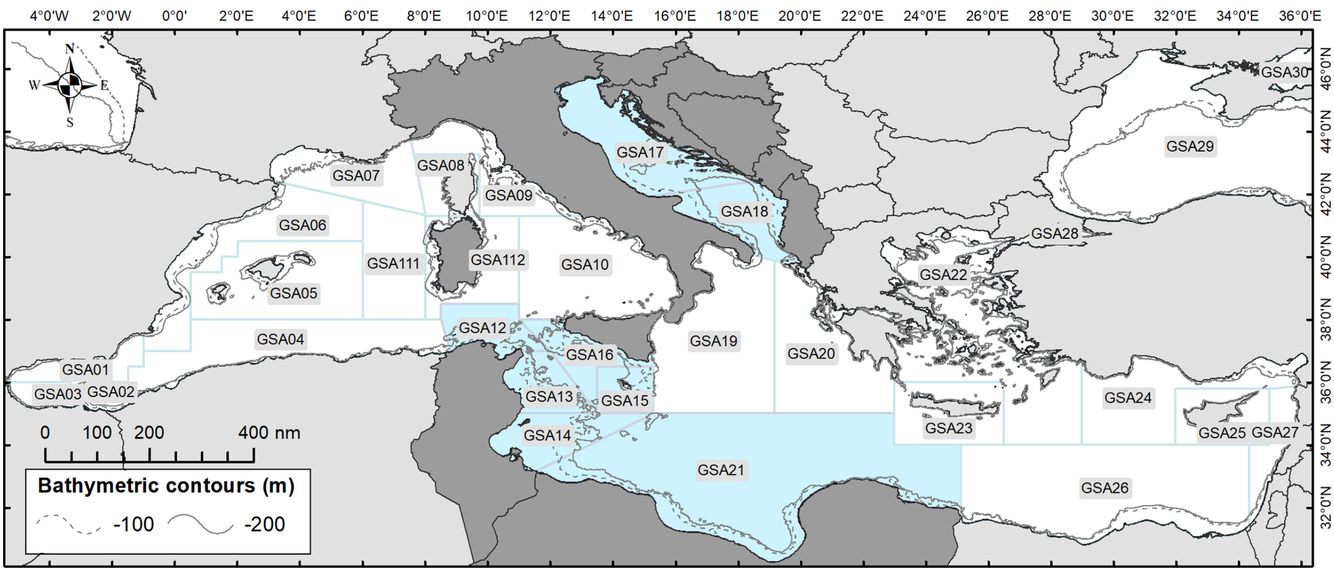

FIGURE 2 Countries (dark grey) and GSAs (light blue) where the participatory mapping of SSF effort was performed

quantify the use of the grounds in terms of number of annual operations by métier, which consists of a combination of fishing gear and target species (i.e. single species or groups of species) (Appendix S1). As target species, we considered the primary objectives of the fishing effort according to specific gears. In particular, fishers were asked to identify the species, which mostly contributed to the value of landings of a specific gear. When more than one species contributed to the value of landings, we identified those catches as "mixed fishery".

The scale of the maps was chosen to allow fishers to orientate themselves and to minimize problems in fishing ground identification. Overall, 93 local maps were printed in A4 paper size to cover the whole study area. Each local map was provided with the statistical GFCM grid (FAO, 2021b), which served for the subsequent georeferencing process. GFCM rectangles, measuring 55.56 by 55.56 km and identified by a 5-digit code (representing latitude and longitude by a mixed letter and number code) were divided into 900 square cells (side, 1.85 km). The combination of the GFCM rectangles code and cell number provided a final identification code for each cell (Appendix S2). This identification code was the key to store in a common spatial database all the information provided by the respondents.

Besides the identification of fishing grounds, the interviewees were asked a number of additional questions, which included (1) how many métiers each fisher had used the previous year; (2) the fishing grounds they had exploited with each métier (which they indicated by tracing polygons on the printed map; (3) how many vessels exploited the same fishing grounds with the same métier; (4) how many months in a year each métier was used by the interviewed fisher; (5) the average number of fishing operations (including both setting and retrieval of passive gears) performed for each gear by the interviewed fisher, estimated as number per week.

In case of overlapping fishing grounds, particular attention was paid to prevent interviewed fishers to report several times the same vessels exploiting their fishing grounds. In particular, in order to overcome this bias, we asked to which harbour the vessels belonged to.

2.4 | Data check

Cross-check validation was achieved at two different levels. At the country level, data collected at each landing site were first checked by the scientists of each national team for possible inconsistencies in terms of fishing gears, target species and fishing effort calculations and then verified against the information gathered at neighbouring landing sites, in order to exclude doubtful or not validated interviews from the analyses. A second data check was based on direct observations in the field, which were performed by joining the fishers on board during routine fishing trips and operations.

2.5 | Data digitization

The fishers' markings on the maps were digitized and saved as vector files. Training sessions on data digitization were conducted during the international workshops, where the scientists worked in QGIS environment (QGIS, 2020).

Fishing effort data were organized and stored as harmonized attributes using 10-digit codes. The attributes described: (i) the Country and GSA to which the fishing grounds belonged as FAO country ISO 2 code (FAO, 2021c) and GSA number, respectively; (ii) the Gear, using the standard International Standard Statistical Classification of Fishing Gear abbreviation (FAO, 2021a) (iii) the Target species, by the 3-alpha code defined in the FAO-ASFIS List of Species for Fishery Statistics Purposes (FAO, 2021a). An example is given in Table 1.

Researchers were given subsets of the vector grid and trained to store the fishing effort values they had collected by editing the grid

TABLE 1 Example of 10-digit coded associated with the Italian (IT) small-scale fleet targeting Common sole (*Solea solea*, Soleidae) (SOL) with trammel nets (GRT) in GSA 17

	Country	GSA	Gear	Species
Digits	1st–2nd digits	3rd–4th digits	5th–7th digits	8th–10th digits
Example	IT	17	GTR	SOL

attributes relating to the fishing cells identified. For each cell, the effort was calculated in terms of the fishing operations carried out in one year (reference year 2018) by fishing métier, as follows:

$$O_{m,i} = N_{Fm,i} \times O_{Wm,i} \times 4 \times M$$

where, $O_{m,i}$ is the total number of fishing operations carried out annually in cell$_i$ by one or more fishers with métier $_m$; $N_{Fm,i}$ is the total number of fishers exploiting the cell $_i$ with one métier $_m$; $O_{Wm,i}$ is the average number of fishing operations carried out weekly by one fisher; and *M* is the number of months a year when the métier was used.

Lastly, national vector files were joined based on the unique identification codes assigned to each grid cell and aggregated into a one-layer geodatabase.

2.6 | Small-scale fisheries participatory mapping

Checked and digitized spatial information was used to map the SSF fishing effort (i.e. annual number of fishing operations) by Métier, Country, GSA, Gear type and Target taxa (Appendix S2).

Each Country-GSA combination was visualized with a 3D scatter plot using km^2/vessel and number of gears used as variables, to evaluate the intensity of their relationship.

The spatial distribution of SSF effort obtained through the participatory mapping was integrated with the bottom trawl data (bottom otter trawl and twin bottom otter trawl) downloaded from the European Marine Observation and Data Network (EMODnet) online database (Fabi et al., 2017; Tassetti et al., 2016). This shapefile was calculated using AIS-based tracking data with a spatial resolution of 0.01° × 0.01°.

3 | RESULTS

A total number of 497 fishers were interviewed in eight Mediterranean countries. The spatial information provided by respondents enabled the thematic mapping of the SSF fishing effort according to a large number of potential combinations in eight countries, eight GSAs, 14 fishing gears and 31 targeted taxa (Appendix S2).

Cross-check data validation highlighted only a few inconsistencies (e.g. identification of target species and fishing gear types), which were resolved during the very first phase of the correction process. Afterwards, on-board observations carried out in each country validated the accuracy of the information related to fishing ground locations.

3.1 | Fishing gear diversity and composition

The results showed that the fishers interviewed employed 49 different métiers (Appendix S2) according to the seasonal availability of the target species. In some cases, they used different gears (e.g. trammel nets and traps for Common cuttlefish, *Sepia officinalis*, Sepiidae) for the same target species in relation to bottom morphology.

The diversity of métiers was highest in east Tunisia (GSA 13, 20 métiers) and lowest (1 métier) in Albania (GSA 18) and Malta (GSA 15), where SSFs mostly target a pool of species with gillnets and trammel nets, respectively. Twenty-five métiers targeted single species (17 fish, five molluscs, three crustaceans; Table 2) using set gears, reflecting their strong selectivity.

The mean value per cell of the annual fishing effort showed a wide variability, ranging from 10 to 74,270 fishing operations per year (Appendix S2).

3.2 | Spatial distribution of the fishing effort

The information provided by the respondents achieved a coastline spatial coverage of 75%–100% in eight of Country-GSA combinations: Albania, Italy GSA 16 and GSA 17; Malta, Slovenia, Tunisia GSA 12, GSA 13 and GSA 14 (Appendix S2). In these areas, the sampling effort ranged from 24 (Tunisia GSA 14) to 78 (Tunisia GSA 12) interviews. The spatial coverage was lowest (<25%) in Croatia (49 interviews) and Libya (40 interviews).

Table 3 illustrates the fishing gears employed in the study area. Gillnets and trammel nets were the most common set gears (11 Country-GSA combinations) to target 19 and 10 taxa, respectively. Trammel nets were used over the widest fishing grounds (30,704 km^2), followed by gillnets (20,076 km^2) and pots (9,069 km^2).

In the Adriatic sea and in most of the Strait of Sicily, trammel nets, gillnets and traps were confined to a narrow coastal strip, since the vast majority of fishing grounds there are located within the three nautical mile (nm) limit (Figures 3 and 4). In contrast, in east and south Tunisia (GSAs 13 and 14) the spatial coverage of these set gears extended offshore; this was true especially for trammels nets in the south (Figure 4).

Merging the SSF spatial information thus collected with AIS-based EMODnet output regarding bottom trawlers yielded integrated maps showing the combined fishing effort of SSFs and bottom trawls in the study area (Figure 4).

The 3D scatter plot (Appendix S3) highlighted two main groups of Country-GSA combinations based on the number of targeted

TABLE 2 List of taxa and number of the Country-GSAs where they were targeted, number of fishing gears used and number of active SSF vessels

Target taxa	Country-GSA, No	Gears, No	Vessels, No
Mixed fishery	12	8	4,099
Common cuttlefish (*Sepia officinalis*, Sepiidae)	7	2	2,634
Caramote prawn (*Melicertus kerathurus*, Penaeidae)	4	1	698
Common octopus (*Octopus vulgaris*, Octopodidae)	4	4	1,638
Mixed sharks (Elasmobranchii)	4	1	116
Spiny lobster (*Palinurus elephas*, Palinuridae)	3	1	144
Common pandora (*Pagellus erythrinus*, Sparidae)	2	3	80
Common sole (*Solea solea*, Soleidae)	2	2	375
European pilchard (*Sardina pilchardus*, Clupeidae)	2	1	32
European squid (*Loligo vulgaris*, Loliginidae)	2	1	56
Garfish (*Belone belone*, Belonidae)	2	2	30
Gilthead seabream (*Sparus aurata*, Sparidae)	2	2	60
Greater amberjack (*Seriola dumerili*, Carangidae)	2	1	32
Mullets (Mugilidae)	2	2	200
Sea breams (Sparidae)	2	1	110
Spottail mantis shrimp (*Squilla mantis*, Squillidae)	2	1	75
Striped red mullet (*Mullus surmuletus*, Mullidae)	2	2	39
Turbot (*Scophthalmus maximus*, Scophthalmidae)	2	1	176
Annular seabream (*Diplodus annularis*, Sparidae)	1	1	120
Bogue (*Boops boops*, Sparidae)	1	1	15
Changeable nassa (*Tritia mutabilis*, Nassariidae)	1	1	290
Common dolphinfish (*Coryphaena hippurus*, Coryphaenidae)	1	1	171
European hake (*Merluccius merluccius*, Merlucciidae)	1	1	16
Mediterranean mussel (*Mytilus galloprovincialis*, Mytilidae)	1	1	10
Picarel (*Spicara smaris*, Sparidae)	1	1	45
Red scorpionfish (*Scorpaena scrofa*, Scorpaenidae)	1	1	10
Salema porgy (*Sarpa salpa*, Sparidae)	1	1	9
Mackerels (Scombridae)	1	1	62
Sea breams (Sparidae) and Mullets (Mugilidae)	1	1	17
Sponges (Porifera)	1	1	200
Swordfish (*Xiphias gladius*, Xiphiidae)	1	1	20

taxa. The group including Tunisia (all GSAs), Italy (GSAs 16 and 17) and Croatia is clearly separated from the group comprising Albania, Italy (GSA 18), Montenegro, Slovenia and Libya. Altogether, a higher number of set gears generally correlated with a higher number of targeted taxa and with wider fishing grounds exploited by each vessel.

3.3 | National specificities

The number of interviews in relation to the number of active vessels was highest in Slovenia (43 interviews and 105 active vessels, 41%), followed by Italy (GSA 18, 18 interviews and 49 active vessels) and Montenegro (45 interviews and 123 active vessels) with around 37% of active fishers interviewed. Interviews with the 129 Tunisian fishers allowed quantifying and mapping 33 métiers covering 75%–100% of coastline of the relevant GSAs. However, these fishers were a small fraction of those operating the 6,696 active Tunisian vessels resulting from the interviews.

In Croatia, despite the relatively high number of interviews (49), the nine métiers identified were not mapped exhaustively, mostly due to the geomorphology of the coastline, where 1,246 islands and islets (accounting for a coastline of about 4,000 km) entail a considerable spatial dispersion of SSF mooring sites. A greater sampling effort would clearly provide a wider coverage. In Libya, the unstable political situation enabled interviews to be conducted only in the area from Misurata to the Tunisian border, for which coverage was nearly complete.

In general, fishing ground extension increased linearly with the number of active vessels; however, beyond 300 vessels the area exploited by SSFs seemed to plateau at a little less than 4,000 km^2

Gear	Country-GSA, No	Taxa, No	Vessels, No	Area, km^2	km^2 vessel
Set gillnets	11	19	3,690	20,076	5.44
Trammel nets	11	10	4,643	30,704	6.61
Pots	7	5	1,275	9,069	7.11
Set longlines	4	2	244	5,053	20.71
Combined nets	3	2	52	822	15.81
Fyke nets	2	1	8	90	11.25
Hand implements	2	2	210	686	3.27
Drift gillnets	1	1	15	14	0.93
Drift longlines	1	1	20	48	2.40
Encircling gillnets	1	1	80	1,159	14.49
Handlines/Pole-lines	1	1	16	24	1.50
Handmade pots	1	1	1,061	391	0.37
Lampara nets	1	2	226	1,211	5.36
Traps	1	1	40	51	1.27

TABLE 3 Fishing gears and number of the Country-GSA where they were used, number of taxa targeted, number of active SSF vessels, total fishing ground extension (km^2) and average extension of fishing grounds exploited by each SSF vessel (km^2)

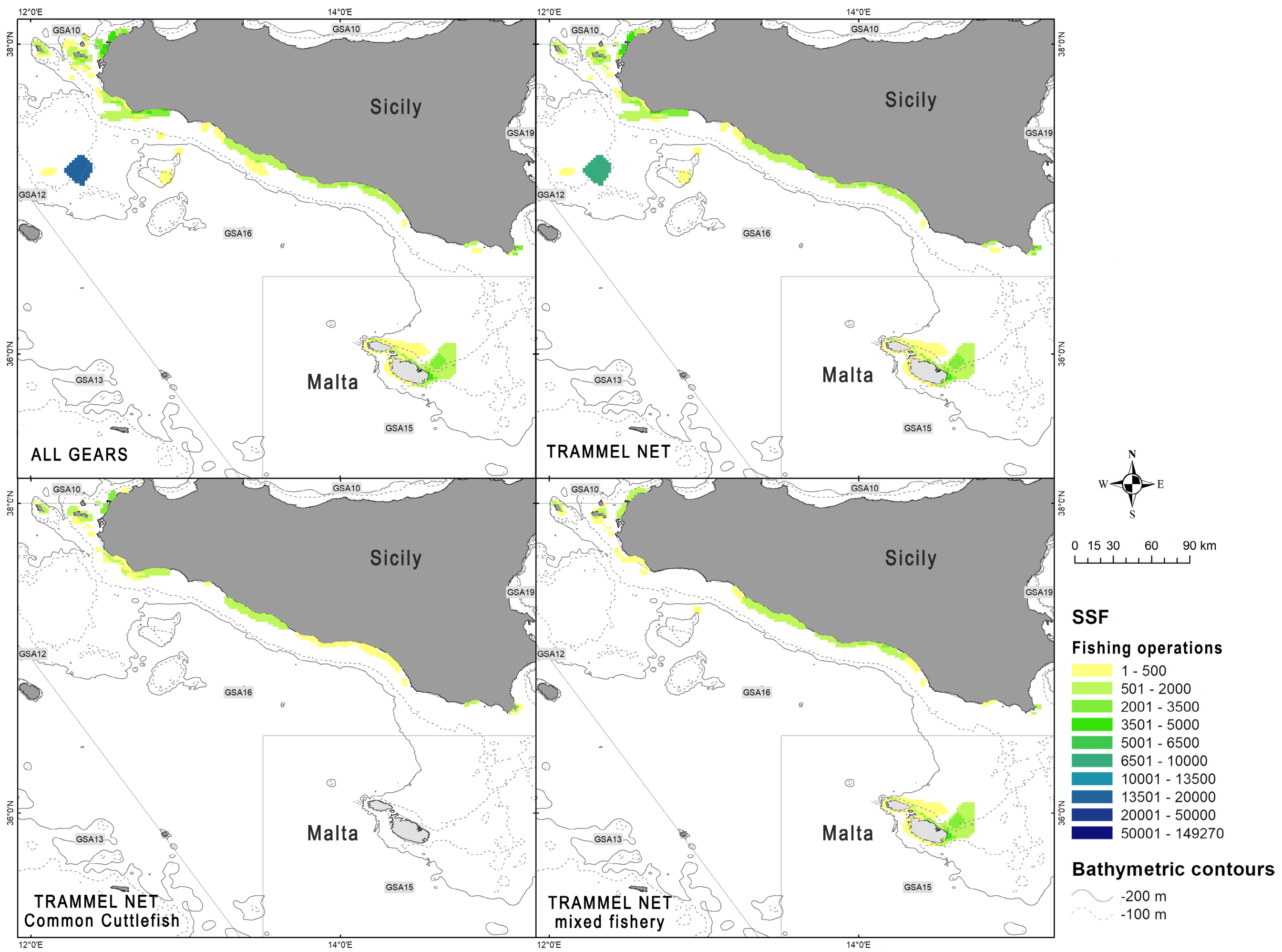

FIGURE 3 Examples of maps showing the number of fishing operations carried out with all SSF gears, trammel nets, trammel nets for Common cuttlefish and trammel nets for mixed fisheries in GSA 15 (Malta) and GSA 16 (Southern Sicily)

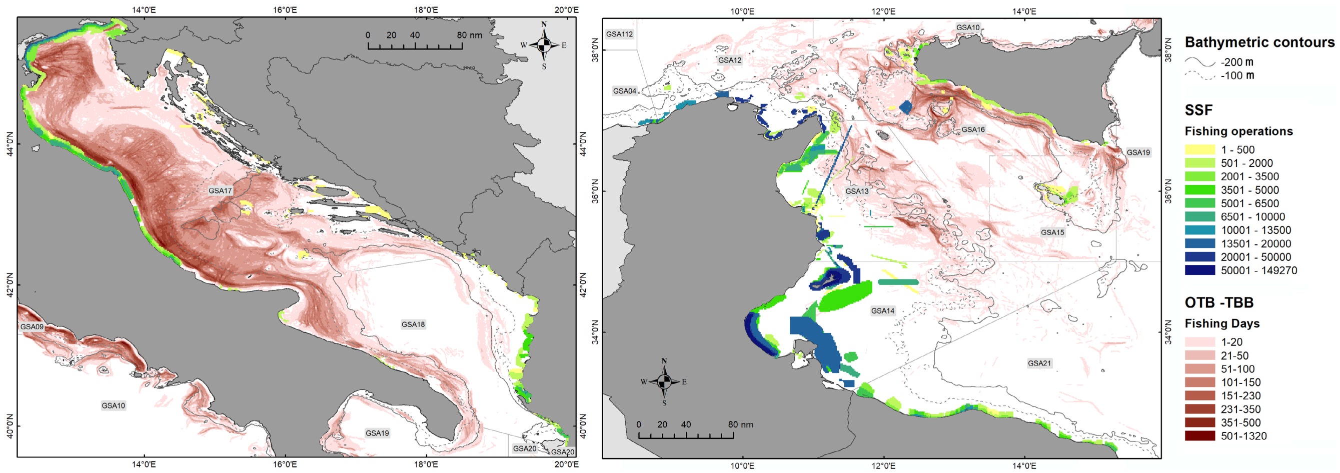

FIGURE 4 Maps showing the number of fishing operations carried out by SSFs and by trawlers (OTB and OTT) in the Adriatic sea and in the Strait of Sicily

(Appendix S4). The only exception was the trammel net used in south Tunisia (GSA 14) to target Caramote prawn (*Melicertus kerathurus*, Penaeidae) a species for which 300 vessels exploited a fishing ground of about 8,500 km^2.

4 | DISCUSSION

Participatory spatial mapping is being employed for a wide range of applications such as indigenous, rural and community development, urban and regional planning, and the management of environmental and natural resources (Brown & Kyttä, 2018). Here, for the first time, we employed these methods to map Mediterranean SSFs in different countries and GSAs. The information obtained from experienced fishers yielded a rich spatial representation of the heterogeneity, complexity and trade-offs typical of Mediterranean SSFs (Papaconstantinou & Farrugio, 2000), providing a better understanding of spatially explicit patterns of fishing pressure according to country, fishery, métier and main target species.

The resulting maps are easy to produce and very informative, and by highlighting the area's most heavily exploited by SSFs provide key information for integrated coastal management and MSP (Ramieri et al., 2019).

The data obtained by the approach described herein may be used alone or in combination with other spatial information to provide a more exhaustive picture of fishery types or, marine resource exploitation in general. For example, combining participatory SSF data and AIS-based information on bottom otter trawlers (Tassetti et al., 2019) allowed mapping the fishing effort for several marine resources (Figure 4) and showed a clear spatial separation between SSF and trawler fishing areas over the continental shelf. Our findings highlight the value of the participatory approach as well as the difficult coexistence of fishing activities using passive and active gears (Moutopoulos et al., 2020).

As per EU Council Regulation 1967/2006, trawling in the Mediterranean is prohibited within three nmi from the coast or within the 50 m isobath, to protect sensitive and priority habitats (e.g. seagrass meadows, coralligenous, nurseries). However, in the western Adriatic sea (Italy, GSA 17) and in southern Sicily (GSA 16), the majority of demersal resources are concentrated in coastal areas (Bastardie et al., 2017; Falsone et al., 2021; Fiorentino et al., 2004); indeed, the integrated maps showed that the fishing pressure of both SSFs and large-scale fleets was highest, respectively, on the inner and outer boundaries of the three nmi strip. Our maps also showed that the respective footprints are clearly separated even in the fine scale. On the other hand, in the areas where the spatial conflicts between large-scale fleets, which use active gears, and SSFs, which use passive gears, are least intense (e.g. in the southern Mediterranean), the SSF footprint extends farther offshore (GSAs 12, 13, 14, 21). In such areas, SSFs are strong and vital and provide a substantial contribution to the local economy (Miret-Pastor et al., 2018).

Given the frequent spatial conflicts between SSFs and trawlers (Farella et al., 2021) and the paucity of spatial information on SSF compared with AIS-tracked large-scale fleets (Ferrà et al., 2018; Kroodsma et al., 2018; Taconet et al., 2019), maps drawn based on data obtained from participatory approaches have the potential to integrate existing data and provide fishery managers with basic but critical information for integrated coastal management and MSP.

4.1 | Strengths and limitations of participatory SSF mapping

Fishers felt comfortable with the interviews and all interviewers reported that respondents usually found it easy to recall and describe their fishing operations, which allowed measuring the fishing effort. In addition, fishers were very precise in recalling the exact number of SSF vessels exploiting their fishing grounds. This was probably favoured by the fact that the position of set gears is indicated by the presence of buoys and, usually, these gears are set at sea for long periods. Therefore, as the extension of the fishing ground represents a limiting factor, fishers were perfectly aware of the number of neighbouring competitors.

The approach, managed by a team of Mediterranean scientists, proved practical, effective and sufficiently robust to describe the great diversity of Mediterranean SSFs and the socio-economic and cultural characteristics of each country. As also recently noted (Azzurro et al., 2019), a well-coordinated Local Ecological Knowledge (LEK) methodology can be applied beyond the local scale, across national borders and jurisdictions, increasing the potential for integrated assessments over a broad scale.

Given the extreme difficulty of obtaining spatially explicit SSF information, the proposed approach contributes to fill major quantitative and spatial data gaps through fishers' participation. Notably, the large sample size and the spatial stratification of interviews prevented significant fishing grounds from being overlooked (McCluskey & Lewison, 2008).

The study outputs, in the form of maps, provide information for several purposes including MSP, coastal zone management, decision-making on the spatial allocation of human activities as well as management processes such as Marine Protected Areas (MPAs) selection and establishment (Walton et al., 2013). Notably, visual maps facilitate information sharing and communication between public authorities and stakeholders, strengthening their involvement in a wide range of decision-making processes (Jankowski, 2009).

Coastal areas exploited by SSF hold great socio-economic potential and the approach proposed here could have several interesting management applications. In a time of growing competition for space and resources and escalating social and political conflicts, as the ones occurring in the Mediterranean area, participatory approaches can be particularly effective to reach the objectives of Blue Growth and MSP. This is mostly due to the fact that such approaches meet the need of governance to be inclusive and transparent in addressing spatial interactions, in particular when multiple stakeholders are involved (Jentoft, 2017). To be effective on this, it is essential for MSP to integrate knowledge on the fine-scale spatial distribution of SSF fishing effort and our data highlight the spatial allocation of this sector in different countries with a fine resolution. This knowledge can be theoretically employed to evaluate any possible spatial conflict, starting from the possible overlap between SSF and other active fishing gears (e.g. trawling, dredges, beam trawls, etc.), but it is also a key information for the spatial planning of MPAs and the possible expansion of aquaculture facilities and offshore wind farms along the coastal areas.

Periodic participatory mapping of the SSF effort could also help track changes in fishing grounds and, indirectly, follow the distribution of target species over time and space, besides detecting possible changes in target species abundance or the arrival of alien species (Ennouri et al., 2021). However, such changes can be detected only if collecting more detailed information on catches (e.g. species distribution and quantities). Indeed, in data-poor fisheries this method could be also used to collect additional information on catches, as well as on the amount and technical features (e.g. mesh size) of gears used, useful to estimate ecological, economic and community-based performance of the fishery (Anderson et al., 2015).

Another important advantage is related to the inherent value of LEK (Azzurro et al., 2019). Specifically, the valorization of fishers' knowledge is expected to reinforce the potential for ecosystem-based management of Mediterranean SSFs (Zelasney et al., 2020). We must finally consider that the involvement of local communities in research frameworks is one of the core themes for co-management and information governance (Mackinson et al., 2011).

Drawbacks of the approach include the fact that fishers may report inaccurate information or even lie on purpose, due to mistrust (Couclelis, 2003). Intentional and accidental errors are a source of uncertainty for map-based data (Close & Hall, 2006); therefore, the quality of collected data is vitally important. Several approaches may be used to assess LEK data reliability (Azzurro & Cerri, 2021; Lèopold et al., 2014). First of all, as mentioned in previous section, respondents were selected by local research teams among the most reliable and knowledgeable active small-scale fishers, with whom relationships of trust have been established as a result of multiple collaborations. Here, in addition, two different levels of data validation were employed: data cross-checks in the field, by asking information on the same area from several fishers, and direct observation by participation in routine fishing trips and operations. Based on this validation process, the authors are confident that this approach could be adopted with limited bias even in routinely programmes. Nevertheless, future investigations could provide quantitative evaluation of the quality of the participatory maps, in terms of agreement and consistency among experts (Azzurro & Cerri, 2021; Drescher & Edwards, 2019), thus improving the transparency of expert judgements when these are used to inform science, improve the co-management and informational governance.

5 | CONCLUSION

Here the knowledge of small-scale fishers was accessed for the first time to map the fishing effort in a wide geographical scale, to obtain information on the local, national and regional level. Mediterranean fishers were keen to collaborate in the participatory mapping effort, regardless of their cultural and political views and conditions. The close connections between the research bodies and local fishers was the base for the further development of a wider network with the coordination of the FAO regional projects AdriaMed and MedSudMed in Adriatic sea and Strait of Sicily, respectively.

We developed and tested a simple, easy to apply and cost-effective (i.e. between 15,000 $ and 18,000 $ per country) approach that allows the SSF effort to be estimated and mapped, even in worst data-poor scenarios. It's encouraging results indicate that the approach could be successfully applied in all the regions where the study of fishers' behaviour and effort distribution would require high specialization skills and considerable effort, time and resources. These fine-scale maps represent valid and robust tools to understand and manage the spatial and temporal dynamics of SSF activities and their impacts on coastal resources.

Overall, the present results provide a satisfactory compromise that balances sampling effort, budget and large-scale mapping and that may contribute to translate the economic, social and ecological policy goals and aspirations of the sustainable EAF into operational objectives, such as fisheries management and conservation planning (Lèopold et al., 2014).

The integrated approach harnessing participatory mapping and AIS data can help bridge the effort spatial data gap through the involvement of key stakeholders (i.e. resource user). It can also be tailored and applied to a wide range of social and ecological contexts, thus contributing to improve the spatial management of natural resource exploitation.

ACKNOWLEDGEMENTS

The Croatian team is grateful to their associates from the Institute of Oceanography and Fisheries, Dario Vrdoljak, Nedo Ivanović and Robert Grgičević, for their valuable assistance in data collection. Open Access Funding provided by Consiglio Nazionale delle Ricerche within the CRUI-CARE Agreement. [Correction added on 14 May 2022, after first online publication: CRUI funding statement has been added.]

AUTHOR CONTRIBUTIONS

F.G. and L.B. conceived the original idea. F.G., E.A., M.S. and A.N.T. led the writing. F.G., A.N.T. and S.G. performed the numerical analyses. All authors contributed to the development and editing of the manuscript.

DATA AVAILABILITY STATEMENT

The AIS trawl data to support the findings in this study are available at MEDSEA_CH5_Product_7 / Change level of disturbance from AIS data combined with habitat vulnerability. EMODnet Medsea Checkpoint (https://doi.org/10.12770/57dbda2c-7125-4252-9ff6-e7d94a1603ea). Spatial data on small-scale fisheries (shapefiles) are available from the corresponding author upon request.

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How to cite this article: Grati, F., Azzurro, E., Scanu, M., Tassetti, A. N., Bolognini, L., Guicciardi, S., Vitale, S., Scannella, D., Carbonara, P., Dragičević, B., Ikica, Z., Palluqi, A., Marčeta, B., Ghmati, H., Turki, A., Cherif, M., Bdioui, M., Jarboui, O., Benhadjhamida, N., … Arneri, E. (2022). Mapping small-scale fisheries through a coordinated participatory strategy. *Fish and Fisheries*, 23, 773–785. https://doi.org/10.1111/faf.12644